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Farmers' perceptions of the degradation of natural resources in lowlands in the Sudano-Sahelian zone: The case of the Nakanbé-Dem sub-watershed in Burkina Faso

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ABSTRACT

The Burkinabe Sahel is characterized by a strong degradation of natural resources. This regression is attributable to natural and anthropogenic factors. The present study concerns the lowlands of the Nakanbé-Dem sub-watershed located in the southern limit of the Sahel. In this area dominated by rain-fed agriculture and extensive livestock farming, wetlands are of paramount importance. In the face of their continued degradation, community participation is necessary for the sustainable management of the lowlands. This study analyzes endogenous indicators of inland valley degradation in the Sudano-Sahelian zone. Semi-structured survey data were collected from 325 farmers in six lowlands. Descriptive statistics and correspondence factor analysis (CFA) was applied. The results show that farmers clearly perceive the degradation of the islands. Farmers use meteorological, floristic, and physical elements to characterize the state of degradation of the islands. The disappearance of several species and the appearance of ubiquitous species allow them to assess the degradation of inland valley lands. These endogenous indicators vary according to gender and education level. The study highlighted the importance of endogenous knowledge in the analysis of inland valley degradation. It suggests the need to take it into account in the implementation of restoration techniques for degraded inland valleys.

Keywords: Endogenous Indicators; Inland Valley Degradation; Perceptions; Watershed; Burkina Faso

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1. Introduction

The lowlands in the intertropical region represent an area of the landscape with a flat or concave bottom. They are located at the head of the hydrographic network, without a watercourse or with a minor bed, and constitute basic drainage axes[1]. They are distinguished from the alluvial plains that follow them downstream and have different hydrology and morphology by the development of the bank bulge, the pedological reworking, and the flooding downstream[2].

In Sahelian countries, lowlands are wetlands that are under increasing anthropogenic pressure with climate variability[3]. The representations of farming communities in these bio-productive units constitute a relevant object of study in the context of global changes. Thus, the adaptation practices developed by producers in response to the negative consequences of climate change depend on their endogenous perception and knowledge of these changes.

In Burkina Faso, the succession of droughts in the 1970s and 1980s in sub-Sahelian Africa resulted in the degradation of ecosystems

and a decrease in productive potential. The Kaya region was particularly affected. The lowlands, formerly considered uncultivated land for agricultural purposes, were used by herders and in some cases as places of worship. Today, these wetlands have become agricultural land coveted by farmers[4].

Land pressure on the lowlands is favored by the potential that these wetlands, multi-use spaces, and considered high agricultural yielding soils offer. The development of lowlands allows producers to take advantage of the available soil and hydrological potentials and socio-economic opportunities[5].

Under the combination of climatic deterioration and human activities, the undeveloped lowlands of the Sudano-Sahelian zone are experiencing an environmental evolution marked mainly by the degradation of slopes, the drying up of watercourses, the lowering of the water table, the disappearance and degradation of the vegetation cover as well as the regression of phytodiversity[6]. Lowland vegetation and flora, characteristic of frequently flooded environments, are also undergoing change[7]. Indicators of change in their environment are perceived by farmers. A local perception is an indispensable approach for studying ecosystem degradation. In addition, it ensures local acceptance of development perspectives and strategies. The objective of this study is to analyze the endogenous indicators of degradation of the lowlands of the Nakanbé-Dem sub-watershed, exploited by men and women, some of whom benefit from support and capacity building for the sustainable management of the lowlands by the State and non-governmental organizations. The working hypothesis is that endogenous indicators of inland valley degradation vary according to gender and level of education.

2. Materials and methods

2.1 Study sites

The study was conducted on the Nakanbé-Dem sub-watershed located in the North-Central Region of Burkina Faso (West Africa). The Nakanbé-Dem sub-watershed, with an area of 165,029 hectares (ha), is distributed between longitudes 1°26'30" W and 0°57'43" W and latitudes 13°58'58"N and 13°31'48"N. It is located in the northern Sudanese phytogeographic sector[8] and experiences a unimodal rainfall regime.

The only rainy season is from June to October. The average annual rainfall varies between 600 and 700 mm. Average annual temperatures vary between 20 and 28 °C during the wet season and are very high in the dry season, 35 to 40 °C, favouring the drying off and water points through evaporation[9]. Geologically, the study area has two types of formations, ante-Berriman composed of granitic formations, and the Birimian composed mainly of volcanic-sedimentary rocks. The Birimian hills form the backbone of the study area. On these geomorphological units, five classes of soils are developed, namely, raw mineral soils, soils that are not very evolved, browned soils, soils with iron and/or manganese sesquioxides, and hydromorphic soils[10]. The geomorphological landscape is organized from the residual landforms to the lowlands, which are preferential areas for the accumulation of runoff from the surrounding hillsides. The lowlands are also areas of high groundwater recharge and it is along these lowlands that water reservoirs and other hydro-agricultural development works are built. Formerly considered uncultivated land for agricultural purposes, reserved for grazing and in some cases for worship, the lowlands are now coveted by farmers because of their richness in exchangeable bases and organic matter. The degraded vegetation formations are mainly composed of parkland savannas in which gallery forests have almost disappeared[10]. Anthropic pressure and climatic deterioration have contributed to the sharp reduction in vegetation cover, leading to an extension of bare soil areas. In the sub-Sahelian sector, corresponding to our study area, the vegetation of wetlands such as lowlands is characterized by *Mitragyna inermis*, *Combretum micranthum*, *Feretia apodanthera*, *Anogeissus leiocarpa*, *Crateva adansonii*, *Flueggea virosa*, *Diospiros mespiliformis*, *Acacia ataxacantha*, *Ximenia americana*, *Gardenia ternifolia*, *Dichrostachys cinerea*, *Tapinanthus globiferus*, *Acacia erythrocalyx*, *Grewia flavescens*, *Terminalia*

glauscessens[11].

The population is made up of 86.27% ethnic Mossi and 9.7% Peulh. It is characterized by average population growth of 2.6%. The literacy rate of individuals aged 15 and over was 24.9% in 2014[12]. More than 80% of the active population is employed in agriculture. Agriculture, which is essentially rain-fed, is extensive and not very mechanized. It is practiced cumulatively with livestock farming, which is the second major activity[12]. The population of the Nakanbe-Dem sub-basin, always in search of fertile land, actively participates in the development of lowlands as a palliative to climatic variability. Our study focused on six lowlands in the Nakanbé-Dem sub-basin, located in the provinces of Sanmatenga and Bam (**Figure 1**).

2.2 Data collection

From a total of 650 farmers, a sample of 325 respondents was selected using stratified random sampling, representing 50% of the lowland farmer population. The strata are based on gender and education level. The statistical unit is a female or male citizen of one of the six inland valley villages who are at least 18 years old and has farmed the inland valley during the past five years. Data were collected using a structured questionnaire. Interviewees were asked to answer questions related to indicators of inland valley degradation, biological taxa that characterize degraded inland valleys, and the causes of degradation and threats affecting these valleys.

Individual interviews were conducted in the local Moore language. However, for the identification of indicator species of the health of the lowlands, a focus group was held with older men and women. Samples from the herbarium were collected for identification and comparison with specimens from the herbarium of the laboratory of plant biology and ecology of the Joseph KI-ZERBO University. The vernacular names were verified with the help of the flora of Thiombiano *et al.*[13] and Nacoulma-Ouédraogo[14]. The nomenclature adopted is that of the catalog of vascular plants of Burkina Faso[15].

2.3 Data analysis

The data were analyzed using descriptive statistics (frequencies and averages) to establish the cause of the degradation of natural resources in the lowlands, the impact of climatic pejorations on these resources, and the dynamics of biodiversity in the lowlands. In addition, a correspondence factor analysis (CFA) was used to analyze the factors of inland valley degradation according to gender and level of education of the farmers using R software. According to some authors, household socioeconomic characteristics such as age, gender, education level, and farm size influence the adaptation and adoption of new methods[16].

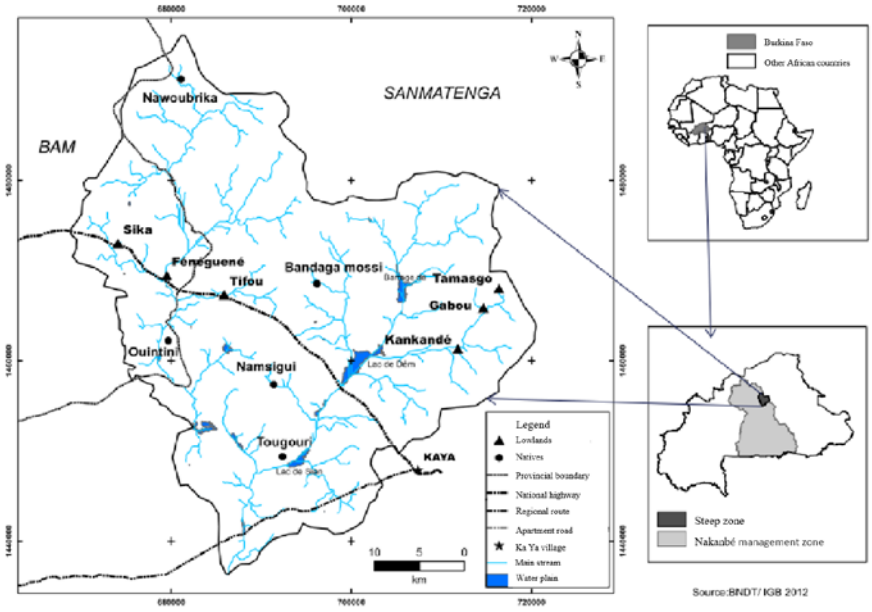

Figure 1. Location of the study sites.

3. Results

3.1 Socio-demographic characteristics

The sample of lowland farmers (**Table 1**) is dominated by men. The number of non-literate farmers is twice that of literate farmers. The farmers surveyed practice mainly rainfed agriculture, with some livestock raising, market gardening, plant exploitation, masonry, and handicrafts.

Table 1. Socio-demographic characteristics of lowland farmers

Gender	Workforce	Percentage (%)
Male	194	59.69
Woman	131	40.30
Level of education		
Non-literate	202	62.15
Literate	123	37.80

3.2 Causes of lowland degradation according to respondents

Figure 2 shows the analysis of farmers' perception of the factors of lowland degradation according to gender and education level. The first two axes explain 95.71% of the explained dimension. Axis 2 shows a gradient in the level of education, separating the literate from the non-literate. Axis 1, separates women from men.

The analysis of the variables that strongly contributed to the inertia of the axes shows that literate men perceive mechanical plowing and flooding as the main factors of degradation of the lowland agrosystems, while non-literate men index violent winds and overgrazing as the main factors of degradation. For literate women, frequent droughts, bush fires, and wood cutting are the main factors of degradation in the lowlands. The shortening of the season is seen as the main factor in the degradation of these lowlands by non-literate women.

3.3 Perceived signs of lowland degradation

Figure 3 shows the analysis of farmers' perception of the signs of degradation of the lowlands according to gender and education level. The first two axes explain 99.20% of the explained dimension.

Both literate and non-literate women perceive the shorter stay of water, soil degradation, and gullying of lowlands as physical indicators of degradation of these wetlands.

Literate men perceive sand and gravel patches and the widening of the central area of the lowlands as the main signs of degradation, while non-literate men perceive the decrease in vegetation cover and the number of trees around the lowlands as the main indicators of their degradation.

3.4 Perception of the state of phytobiological resources in degraded lowlands

Aggregate data on the citations of indicator plant species for the state of the inland valleys allowed us to select those that were most widely accepted by the inland farmers. Thus, it appears that the Nakanbe-Dem lowland farmers perceive the phytobiological evolution of their lowlands. They recognize the species that are currently proliferating in degraded inland valleys as well as those that have disappeared from these sites (**Table 2**).

4. Discussion

4.1 Perception of degradation factors in the lowlands

The lowlands of the Nakanbé-Dem sub-watershed are increasingly exploited for agriculture. More men than women are exploiting these lowlands. This trend is general in the Sudano-Sahelian zone or the lowlands have been experiencing intense agricultural exploitation in recent decades due to the fertility of their soils and their hydromorphic character[3,5]. The exploitation of lowlands constitutes one of the adaptation strategies of farmers to climate change. As a result, women's access to inland valleys is increasingly reduced at the expense of men. Research has shown that the same access trend is observed when inland valleys are developed for agricultural use[18].

The rural communities of the Nakanbé-Dem sub-watershed have a good perception of the degradation of the lowlands and the factors that cause it. This perception varies according to gender and education level. This can be seen in the correspondence factor analysis where Axis 2 shows a gradient of the level of education while Axis 1 separates women from men.

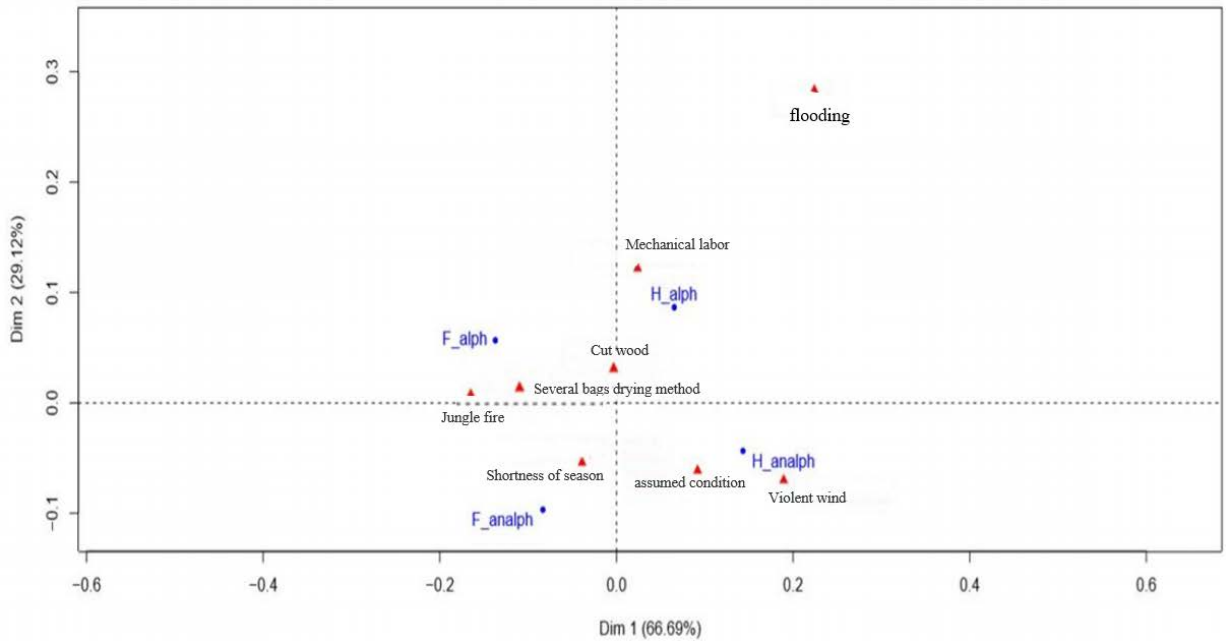

Figure 2. Analysis of factors of lowland degradation by gender and literacy level.
F_alph: Literate women; F_analph: Non-literate women; H_alph: Literate men; H_analph: Non-literate men.

Table 2. Status of phytobiological resources in the lowlands

Proliferating trees in degraded lowlands				
Local name	**Species**	**Family**	**TP**	**TB**
Kiègla	*Balanites aegyptiaca (L.) Del.*	Zygophyllaceae	SZ	mph
Pennga	*Acacia nilotica (L.) Willd. ex Del*	Fabaceae	SZ	mph
Mugunuga	*Ziziphus mauritiana Lam.*	Rhamnaceae	Pal	mph
Randga	*Combretum micranthum G. Don*	Combretaceae	S	mph
Banguemdé	*Piliostigma reticulatum (DC.) Hochst.*	Fabaceae	SZ	mph
Vanished trees in degraded lowlands				
Gonpagnatga	*Senegalia senegal (L.) Britton*	Fabaceae	SZ	mph
Kombrayinogo	*Boswellia dalzielii Hutch.*	Burseraceae	S	mph
bargôdga	*Annona senegalensis Pers.*	Annonaceae	S	nph
siiga	*Anogeissus leiocarpa (DC.) Guill. & Perr.*	Combretaceae	S	mph
Vouaga	*Bombax costatum Pellegr. et Vuillet.*	Malvaceae	S	mph
Yilga	*Mitragyna inermis (Willd.) Kuntze*	Rubiaceae	SZ	mph
Lènga	*Ximenia americana L.*	Olacaceae	Pan	nph
Faranguemtoula	*Capparis sepiaria L. (C. corymbosa Lam.)*	Capparacae	S	Lnph
Kaanka	*Diospyros mespiliformis Hoschstex A. DC.*	Ebenaceae	Pal	mph
Wilinwiga	*Guiera senegalensis J. G. Gmel.*	Combretaceae	SZ	mph
Kuka	*Khaya senegalensis (Desr.) A. Juss.*	Meliaceae	S	mph
Nayuponka	*Pterocarpus erinaceus Poir.*	Fabaceae	SZ	mPh
Kalgmetoèga	*Crateva adansonii DC.*	Capparaceae	Pal	mph
Proliferating grasses in degraded lowlands				
Pintme-pin	*Digitaria horizontalis Willd.*	Poaceae	Pan	Th
Kimbgo	*Pennisetum pedicellatum Trin.*	Poaceae	Pal	Th
Roumroumbi	*Hyptis spicigera Lam.*	Lamiaceae	Pan	Th
Sangodo	*Senna obtusifolia (L.) Irwin & Barneby*	Fabaceae	Pan	Th
Wango	*Striga hermonthica (Delile) Benth.*	Orobanchaceae	AT	He
Monpoaka	*Andropogon gayanus Kunth*	Poaceae	S	He
Naasar-gonsé	*A canthospermum hispidum DC.*	Asteraceae	Pan	Th

Table 2. (*Continued*)

Local name	Species	Family	TP	TB
Boango-yando	*Commelina benghalensis L.*	Commelinaceae	Pan	Ch
Kansaga	*Sporobolus pyramidalis P.Beauv.*	Poaceae	AA	He
Extirpated grasses in degraded lowlands				
Gnantré	*Andropogon pseudapricus Stapf*	Poaceae	AA	Th
Kaloêga	*Schizachyrium sanguineum (Retz.) Alston*	Poaceae	Pan	He
Koulmoogo	*Oryza longistaminata A. Chev. & Roehr.*	Poaceae	AM	He
Gouila	*Nymphea lotus L.*	Nympheaceae	Pan	Ge
Goadba	*Stylochaeton hypogaeus Lepr.*	Araceae	S	Ge
Doudouma	*Vetiveria nigritana (Benth.) Stapf*	Poaceae	SZ	He
Remsa	*Alysicarpusovalifolius (Schum. & Thonn) J. L*	Fabaceae	Pal	Th
Kiwaré	*Cymbopogon giganteus Chiov.*	Poaceae	AT	He
Kalgên yâaga	*AndropogontectorumSchumach. & Thonn.*	Poaceae	S	He
Pouloumdi	*Imperata cylindrica (L.) P. Beauv.*	Poaceae	Pan	Ge
Kansaga	*Sporobolus pyramidalis P. Beav.*	Poaceae	AA	He

TP: Phytogeographic type; AA: Afro-American species; AM: Afro-Malagasy species; AT: Tropical Africa; Pal: Paleotropics; Pan: Pantropics; PRA: Pluri-regional African species; S: Sudanese species; SZ: Sudan-Zambezi species. TB: Biological type; Ch: Chamephyte; Chsl: Chamephyte under woody; Ge: Geophyte; He: Hemicryptophyte; Lnph: Liane Nanophanerophyte; Lth: Liane therophyte; mph: Mesophanerophytes; nph: Nanophanerophytes; Ph: Phanerophytes; Th: Therophytes.

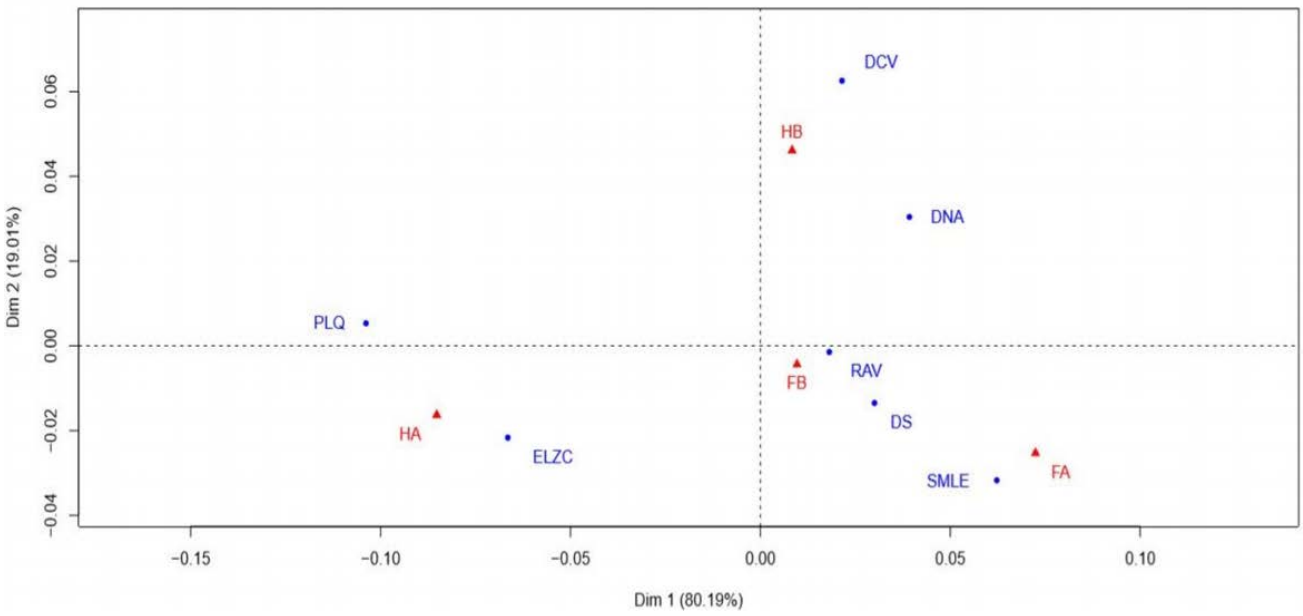

Figure 3. Factor analysis of threat perception by gender and education level.
FA: Literate women; FB: Non-literate women; HA: Literate men; HB: Non-literate men; DCV: Decrease in vegetation cover; DNA: Decrease in the number of trees; DS: Soil degradation; ELZC: Enlargement of the central zone; PLQ: Sand or gravel spreading; RAV: Ravinement; SMLE: Less stay of the water.

Farmers in the Nakanbe-Dem sub-watershed are aware that some of their practices degrade the lowlands. The literate men list mechanical plowing as an anthropogenic factor in the degradation of the lowlands. Mechanical plowing accentuates water erosion and the transport of sediments that can fill in the lowland beds. In a context where soils are shallow, plowing degrades lowland soils. The education and training received by some lowland farmers allow them to perceive the negative impact of technologies such as plowing on lowland soils. This result corroborates Sofoluwe *et al.*[19] that education and training increase farmers' ability to use a variety of information and influence the adoption of technological innovations. Therefore, there is a need to improve formal and informal education in rural communities for sustainable use of inland valleys.

Overgrazing is perceived by non-literate men as the main anthropogenic factor threatening the lowlands, probably because of the high density of livestock in the Nakanbé-Dem zone. Da *et al.*[9] note that agropastoral practices in the north-central region have resulted in soil degradation and a notable decline in fertility, including in wetlands. The density of livestock is higher than the carrying capacity of the lowlands. Overgrazing degrades lowland vegetation, and compacts soils that become susceptible to encrustation[20-22].

Finally, non-literate women perceive wood cutting and bush fires as the main anthropogenic factors of lowland degradation. In this zone, the dynamics of the occupation of the lowlands are also the consequence of the practice of burning associated with the felling of trees for charcoal making and obtaining firewood[23]. These actions expose the lowlands to various problems including loss of their potential, degradation of the surrounding slopes, and plateaus[21,22]. These poor practices are perceived by non-literate women in particular. This may be due to the fact that in rural areas, the place and role of women in the kitchen predispose them to notice the degradation of the "firewood" resource in lowland ecosystems[13]. In addition, faced with the recurrent instability of agricultural production, rural populations, particularly women, are developing survival strategies, one of the most common of which is the use of agroforestry park tree products (fruits, flowers, seeds, leaves, bark, roots) as an alternative livelihood[24].

The climatic factors of inland valley degradation most noted by these communities are pockets of drought, short season, high winds, and flooding. Literate men perceive high winds as the main cause of lowland degradation, while non-literate men point to flooding. For literate women, the increase in the frequency of dry spells was cited as the main climatic factor in degradation, while for non-literate women, the decrease in the number of rainy days was cited. Research has shown that gender and education level influence perceptions of climate change as well as adaptation options[19,25,27]. For example, women are more likely to perceive the effects of climatic factors such as pockets of drought and reduced rainy season on their agricultural activities. This is certainly the basis for their perception of these factors as important in the degradation of the lowlands. In addition, women are more affected by the early drying up of ponds and streams, which serve as supply points[28].

4.2 Perception of biophysical indicators of inland valley evolution

The communities of the Nakanbe-Dem sub-watershed perceive the degradation of the lowlands through physical indicators (widening of the central zone, sandy-gravel veneer, soil erosion, gullying, and early drying of the lowlands) and biological indicators (decrease in vegetation cover and decrease in the number of trees). These biophysical indicators of lowland degradation vary according to gender and education level. Several authors have shown that socio-economic characteristics of rural communities such as gender and education level influence the perception of inland valley degradation[13,19]. The shorter stay of water in the lowlands is well perceived by women because they get water from these wetlands[28]. In addition to this physical indicator of lowland degradation, women also perceive soil degradation and lowland gullying as key physical indicators of degradation. The level of education had no effect on women's perception of signs of bottomland degradation.

Non-literate men perceive the degradation of the lowlands through the state of the vegetation stand, in this case the decrease in the vegetation cover and the number of trees. The size and density of woody plants are a criterion often used to assess the health of the lowlands[25,26]. As for literate men, sandy-gravel veneers as well as the enlargement of the central zone of the lowlands are the main signs of degradation of these wetlands. Indeed, in the Sahelian zone, erosion by rainwater digs gullies in places and lateral regressive erosion on the banks of the lowlands widens their bed and causes sand deposits[29]. This aspect is perceived by these communities, especially literate men.

4.3 Perception of the state of phytobiological resources in degraded lowlands

Pressure on the lowlands is causing significant

alteration of the vegetation communities in these wetlands. This indicator is well perceived by rural communities who recognize some of the species that have disappeared in the lowlands as well as species that are proliferating as a result of the degradation of these sites (**Table 2**).

Among the woody plants proliferating in degraded lowlands, farmers commonly identify *Balanites aegyptiaca* (L.) Del; *Acacia nilotica* (L.) Willd. ex Del; *Ziziphus mauritiana* Lam; *Combretum micranthum* G. Don and *Piliostigma reticulatum* (DC.) Hochst. Lompo[30] also noted that these species are abundant in the agrosystems of the Sahel zone. These identified species are dominated by individuals with a greater degree of sclerophyll (plants whose leaves turn into spines to limit water loss due to drought). Khoudia *et al*.[31] showed that the abundance of such species in an environment is explained by their adaptability to degraded pedoclimatic conditions.

Herbaceous species identified by farmers as proliferating in lowlands include *Digitaria horizontalis* Willd, *Pennisetum pedicellatum* Trin., *Hyptis spicigera* Lam and *Senna obtusifolia* (L.) Irwin & Barneby. Soulama[31] showed that the presence of these species in a wetland is related to the degradation of the wetland by grazing. In addition to grazing, several other factors (wood cutting, bush fires, etc.) contribute to the establishment of these ubiquitous species in these lowland environments. The analysis of the flora identified by farmers in degraded lowlands corroborates several authors who have characterized the flora of degraded environments[31-33]. Indeed, the cited taxa are dominated by therophytes (annual seed plants) and annual species with multi-regional distribution (Pantropical, Paleotropical, and Afrotropical).

As for woody species disappearing in the lowlands, farmers identify wetland species such as African birch (*Anogeissus leiocarpa*), and African ebony (*Diospyros mespiliformis*) and *Mitragyna inermis* also known as *Mitragyna africana*. These species are recognized by several authors as characteristic of frequently flooded environments[33-35]. The modification of water regimes would be a factor that has favored the elimination of these species that once gave a wet tone to these lowlands. Thus, farmers clearly perceive the erosion of plant biodiversity in lowland ecosystems.

Communities in the Nakanbe-Dem sub-watershed identify species such as Andropogon pseudapricus Stapf, Andropogon tectorum Schumach. & Thonn, *Schizachyrium sanguineum* (Retz.) Alston, as having disappeared from the lowlands. Floristic analysis of species identified by farmers corroborates several authors who have shown that species of the genus Andropogon indicate a fertile, non-degraded environment[32,33]. On the contrary, the disappearance of these species from lowland environments reflects the degradation of these sites.

As much as farmers recognize the degradation of inland valleys through the identification of certain extinct floristic species, the good health of inland valleys ecosystems is recognized through the proliferation of other species. The disappearance of several species and the appearance of ubiquitous species can be used to assess the degradation of inland valleys. This endogenous knowledge of degradation indicator plants can be used in community environmental education programs.

5. Conclusion

Our study aimed to investigate the biophysical indicators of inland valley degradation of farmers in the Nakanbe Dem sub-watershed. The results show that the farmers exploiting the lowlands have knowledge of the factors of degradation of the lowlands and perceive the signs of degradation as well as the species that reflect the health of the lowlands. The gender and education level of farmers influence their perception of indicators of inland valley degradation. These indicators depend on gender and education level. This endogenous knowledge could be used to support participatory restoration programs for degraded lands.

Conflict of interest

The authors declare that they have no conflict of interest in this article.

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